

City University  
School of Engineering and Mathematical Sciences

MSc in Telecommunication and Networks

EPM775 Multiservice Communication Networks

Laboratory Assignment

## Network Simulation using OPNET

November 2006



## Laboratory 1

### Switched Local Area Networks

**Overview** This Lab is designed to demonstrate the need for implementation of switches in the design of local area networks. In this Lab, the students will design a 16-station LAN using first a simple hub, and then a switch and two hubs. The performance of the local area network in the two scenarios will then be compared.

### Procedure

#### Create a New Project

In this first phase you will open and name your project and name the first simulation scenario. The first simulation scenario will consist of 16 networked stations (PCs) and one hub. In this first phase you will specify the geographic size of the network.

1. Start the **OPNET IT Guru Academic Edition** → Choose **New** from the **File** menu
2. Select **Project** and click **OK** →; Name the project **<your email username>\_Lab1** (e.g. xy123\_Lab1) → Name the scenario **OnlyHub**; Click **OK**
3. In the *Startup Wizard:Initial Topology* dialog box, make sure that **Create Empty Scenario** is selected → Click **Next** → Choose **Office** from the *Network Scale* List → Click **Next** three times → Click **Finish**.
4. **Close** the *Object Pallete* dialog box.

#### Create the Network

To create our switched LAN:

1. Select **Topology** → **Rapid Configuration**. From the drop-down menu choose **Star** and click **OK**.
2. Click the **Select Models** button in the *Rapid Configuration* dialog box. From the *Model List* drop-down menu choose **ethernet** and click **OK**.
3. In the *Rapid Configuration* dialog box, set the following six values: **Center Node Model = ethernet16\_hub, Periphery Node Model = ethernet\_station, Link Model = 10BaseT, Number =16, Y=50, and Radius = 42** → Click **OK**.

Remember that 10BaseT link represents an Ethernet connection operating at 10Mbps.

4. Right-click on **node\_16**, which is the hub → **Edit Attributes** → Change the **name** attribute to **Hub1** and click **OK**.
5. Now that you have created the network, it should look like the network on Figure below.

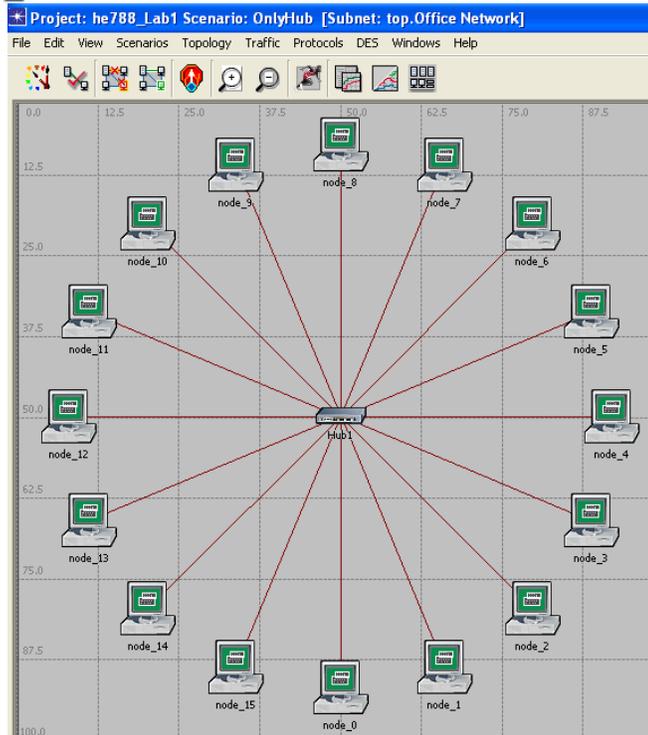


Fig.1

6. Make sure to save your project.

### Configure the network nodes

Here you will configure the traffic generated by the stations.

1. Right-click on any of the 16 stations (node\_0 to node\_15) → **Select Similar Nodes**.  
Now all stations in the network are selected.
2. Right-click on any of the 16 stations → **Edit Attributes**.
  - a. Check the **Apply Changes to Selected Objects** check box. This is important to avoid reconfiguring each node individually.
3. Expand the hierarchies of the **Traffic Generation Parameters** attribute and the **Packet Generation Arguments** attribute → Set the following four values:

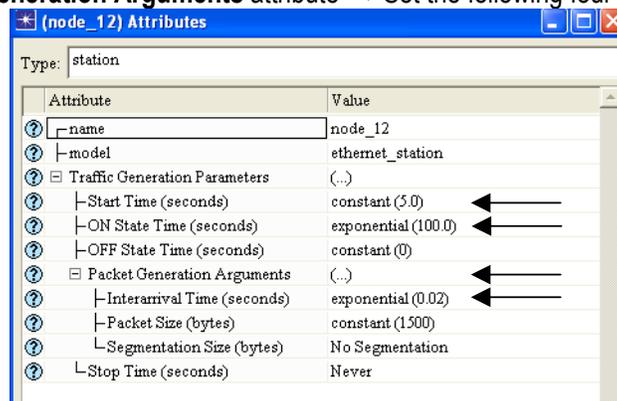


Fig 2

4. Click **OK** to close the attribute editing window. Save your project

Note here that we have introduced a traffic generation at each node. The traffic model follows a well-known ON-OFF model, in which each node switches between On state in which the traffic is generated, and OFF state in which there is no traffic. The duration of ON and OFF states is random, and in this example follows exponential distribution. In this example, the duration of OFF state is 0.

### Choose Statistics

To choose the statistics to be collected during the simulation:

1. Right-click anywhere in the project workspace and select **Choose Individual Statistics DES** from the pop-up menu.
2. In the *Choose Results* dialog box, choose the following 4 statistics:
  - a. **Ethernet Delay** – this represents the end-to-end delay of all packets received by all the stations.
  - b. **Traffic Received (in packets/sec)** by the traffic sinks across all nodes
  - c. **Traffic Sent (in packets/sec)** by the traffic sources across all nodes
  - d. **Collision count** is the total number of collisions encountered by the hub during packet transmissions.
3. Click **OK**.

### Configure the Simulation

Here we need to configure the duration of the simulation:

1. Click on the **Configure / Run Simulation** button.
2. Set the duration to be **2.0 minutes**
3. Click **Apply** and then **Cancel**

### Duplicate the Scenario

The network we just created utilizes only one hub to connect the 16 stations. We need to create another network that utilizes a switch and see how this will affect the network performance. To do that we will create a duplicate of the current network.

1. Select **Duplicate Scenario** from the **Scenarios** menu and give it the name **HubAndSwitch** → Click **OK**.
2. Open the **Object Palette** by clicking on . Make sure that **Ethernet** is selected in the pull-down menu on the object palette.
3. We need to place a hub and a switch in the new scenario. (they are circled in the figure below).
4. To add the **Hub**, click its icon in the object palette → Move your mouse to the workspace → Click to drop the hub at a location you select. Right click to indicate you are done deploying hub objects
5. Similarly, add the **Switch**

6. Close the **Object Palette**
7. Right-click on the new hub → **Edit Attributes** → Change the *name* attribute to **Hub2** and click **OK**.
8. Right-click on the switch → **Edit Attributes** → Change the *name* attribute to **Switch** and click **OK**
9. Reconfigure the network of the **HubAndSwitch** scenario so that it looks like the following one.

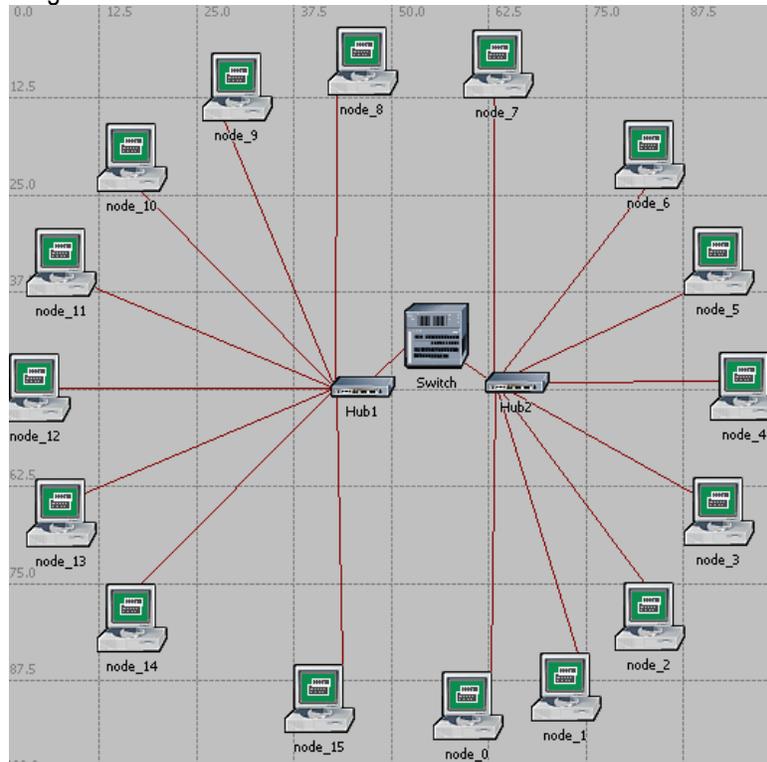


Fig 3.

Hints:

- To remove a link, select it and choose Cut from the Edit menu (or simply hit the Delete key). You can select multiple links and delete them all at once.
- To add a new link, use the 10BaseT link available in the Object Palette.

10. Save the Project.

### Run the Simulation

To run the simulation for both scenarios simultaneously:

1. Select **Manage Scenarios** from the **Scenarios** menu.
2. Change the values under the **Results** column to **<collect>** (or **<recollect>**) for both scenarios. Compare to the following figure.

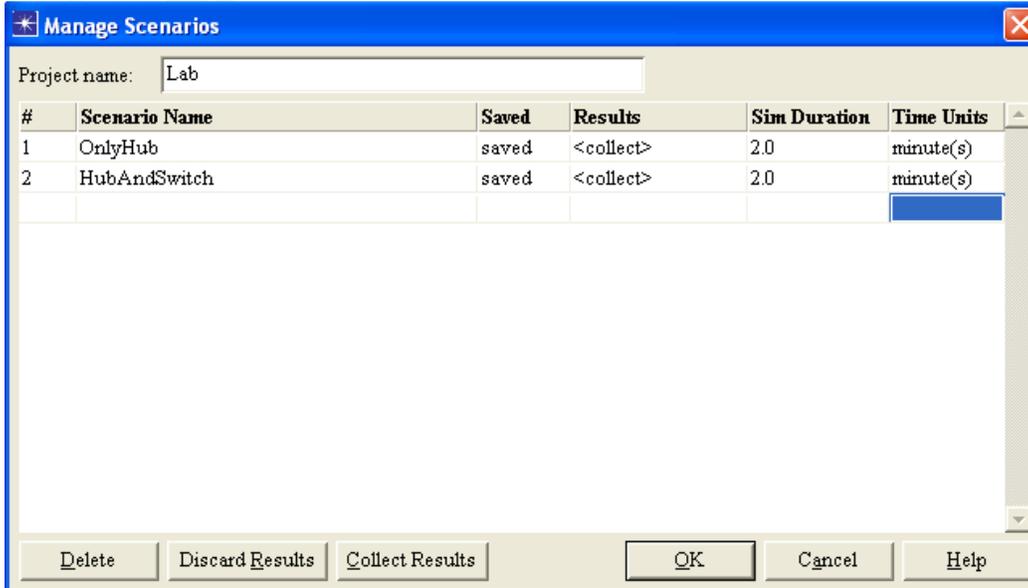


Fig 4

3. Click **OK** to run the two simulations.
4. After the two simulations runs complete, one for each scenarios, click **Close**.
5. Save your project.

#### View the Results

To view and analyze the results:

1. Select **Compare Results** from the **Results** menu. (Or right click in the workspace).
2. Change the drop-down menu in the lower-right part of the *Compare Results* dialog box from **As Is** to **time\_average**.
3. Select the **Traffic Sent (packets/sec)** statistics and click **Show**.
4. Select the **Traffic Received (packets/sec)** statistics and click **Show**.
5. Select the **Delay (packets/sec)** statistics and click **Show**.
6. Select the **Collision Count (packets/sec)** statistics and click **Show**.
7. On the resulting graph right-click anywhere on the graph area → Choose **Add Statistics** → Expand the hierarchies as shown below → Select the **Collision Count** statistics for **Hub2** → Change **As Is** to **time\_average** → Click **Add**.
8. Save your project.

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Laboratory 2

## RIP: Routing Information Protocol

**Objective:** To use OPNET to analyse the performance of RIP, a routing protocol built on a distance-vector routing algorithm. To examine the formation and exchange of routing tables. To observe how RIP is affected by link failures.

### Procedure

#### Create a New Project

1. Start **Opnet IT Guru Academic Edition** ⇒ choose **New** from the **File** menu
2. Select **Project** and click **OK** ⇒ Name the project **<your student number>\_EE2480\_Lab2** and the scenario **NO\_Failure** ⇒ click **OK**.
3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty Scenario** is selected ⇒ Click **Next** ⇒ select **Campus** from the Network Scale list ⇒ Click **Next** 3 times ⇒ click **OK**.

#### Create and Configure the Network

*Initialize the network:*

1. The Object Palette dialog box should now be on top of your project workspace. If it is not there, click on the icon in the menu. Make sure that the **internet\_toolbox** is selected from the pull-down menu on the object palette.
2. Add to the project workspace the following objects from the palette: one **ethernet\_slip8\_gtwy** router and two **100BaseT\_LAN** objects.
  - a. To add an object from the palette, click its icon in the object palette ⇒ move your mouse to the workspace ⇒ click to place the object ⇒ right-click to stop creating objects of that type.
3. Use bidirectional **100BaseT** links to connect the objects you just added as in Figure 1. Also, rename the objects as shown (right-click on the node ⇒ **Set Name**).
4. Close the Object Palette dialog box.
5. Save your project.

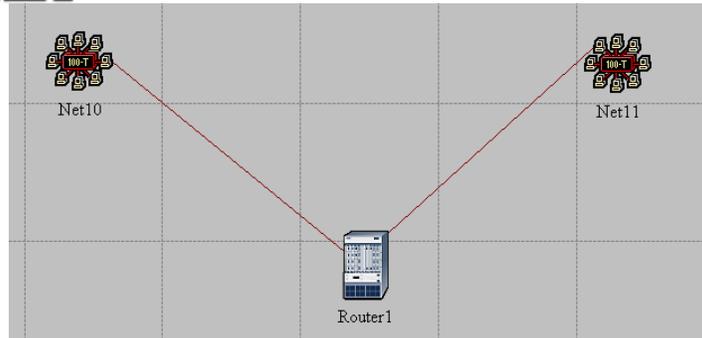


Figure 1

Configure the Router:

1. Right-click on **Router1** ⇒ **Edit Attributes** ⇒ **Reports**
  - a. **IP Forwarding Table = Export at End of Simulation**. This asks the router to export its routing table at the end of the simulation to the simulation log.
  - b. **RIP Routing Table = Export at End of Simulation**
2. Click **Ok** and then save the project.

Add the remaining LANs:

1. Highlight or select simultaneously (using shift + left-click) all 5 objects that you currently have in the project workspace (one router, two LANs, and two links). You can click-and-drag a box around the objects to do this.
2. Press Ctrl+C to copy the selected objects and then Ctrl+V to paste them.
3. Repeat Step 2 three times to generate three new copies of the objects and arrange them in a way similar to the following figure. Rename all objects as shown.
4. Connect routers, as shown, using **PPP\_DS3** links. The PPP\_DS3 link has data rate of 44.736Mbps.

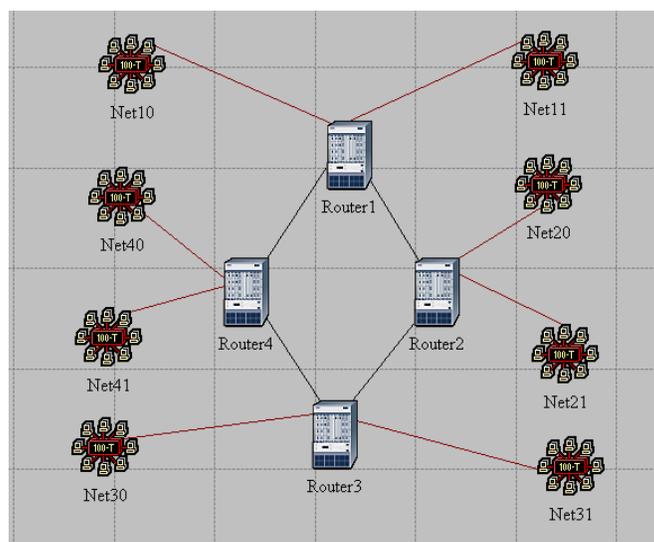


Figure 2

### Choose the Statistics

To test the performance of the RIP protocol, we will collect the following statistics:

1. Right-click anywhere in the project workspace and select **Choose Individual Statistics** from the pop-up menu.
2. In the Choose Results dialog box, check the following statistics:
  - a. **Global Statistics** ⇒ **RIP** ⇒ **Traffic Sent (bits/sec)**
  - b. **Global Statistics** ⇒ **RIP** ⇒ **Traffic Received (bits/sec)**
  - c. **Nodes Statistics** ⇒ **Route Table** ⇒ **Total Number of Updates**
3. Click **OK** and then save your project.

RIP traffic is the total amount of RIP update traffic in bits sent/received per second by all the nodes using RIP as the routing protocol in the IP interfaces in the node. Total number of updates is the number of times the routing table at this node gets updated (e.g. due to a new route addition, an existing route deletion, and/or a next hop update).

### Configure the Simulation

Here we need to configure some of the simulation parameters:

1. Click on  and the Configure Simulation window should appear.
2. Set the duration to be **10.0 minutes**
3. On the right-side panel, click on **Input** ⇒ **Global Attributes** tab and change the following attributes:
  - a. **IP Dynamic Routing protocol = RIP**. This sets the RIP protocol to be the routing protocol of all routers in the network.
  - b. **IP Interface Addressing Mode = Auto Addressed/Export**.
  - c. **RIP Sim Efficiency = Disabled**. If this attribute is enabled, RIP will stop after the "RIP Stop Time". But we need the RIP to keep updating the routing table in case there is any change in the network (as we will see in the second scenario).
4. Click **Ok** and save the project.

Auto Addressed means that all IP interfaces are assigned IP addresses automatically during simulation. The class of addresses (A, B or C) is determined on the basis of the number of hosts in the designed network. Subnet masks assigned to these interfaces are the default subnet masks for that class.

Export causes the auto-assigned IP interfaces to be exported to a file <net\_name>ip\_address.gdf that gets saved in the primary model directory.

### Duplicate The Scenario

In the network we just created, the routers will build their routing tables, and then they will not need to update them further because we did not simulate any node or link failures. In this second scenario we will simulate failure so that we can compare the behaviour of the routers in both cases.

1. Select **Duplicate Scenario** from the **Scenarios** menu and name it **Failure** ⇒ Click **OK**.
2. Open *Object Palette* by clicking the icon. Select the **Utilities** palette from the drop-down menu.
3. Add a **Failure Recovery** object to your workspace and make it **Failure** as shown ⇒ Close the *Object Palette* dialog box.

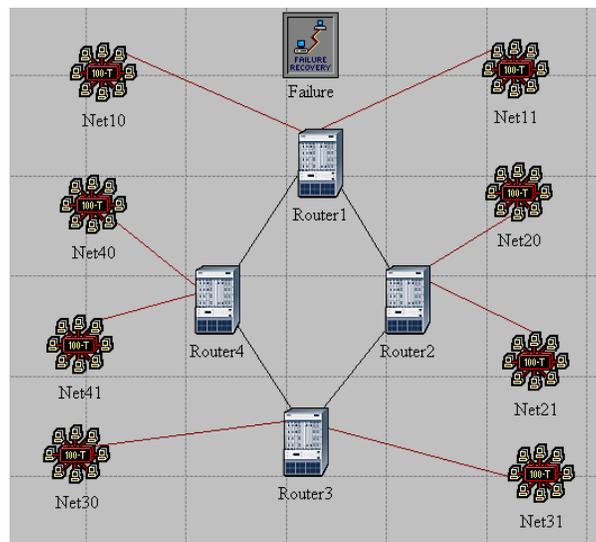


Figure 4

4. Right-click on the **Failure** object ⇒ **Edit Attributes** ⇒ Right-click on the **Link Failure/Recovery Specification** hierarchy ⇒ Select **Edit** ⇒ Put 1 in rows, as in figure below:

This will “fail” the link between Router1 and Router2 200 seconds into the simulation.

5. Click **Ok** and save the project.

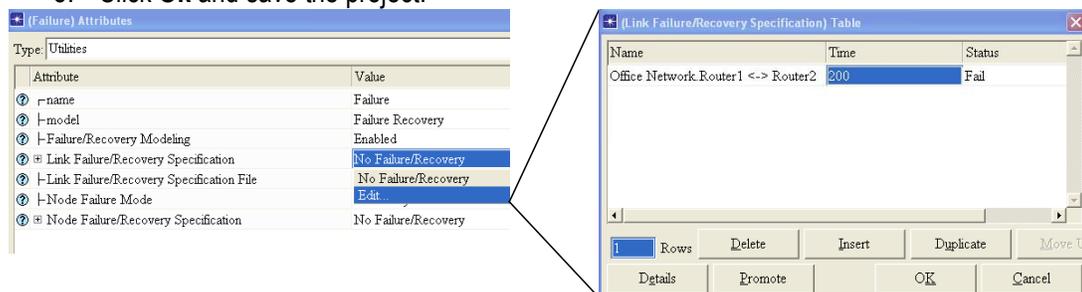


Figure 5

## Run the Simulation

To run the simulation for both scenarios simultaneously:

1. Go to the **Scenarios** menu ⇒ Select **Manage Scenarios**.
2. Change the values under the **Results** column to <collect> (or <recollect>) for both scenarios. Compare to the following figure.

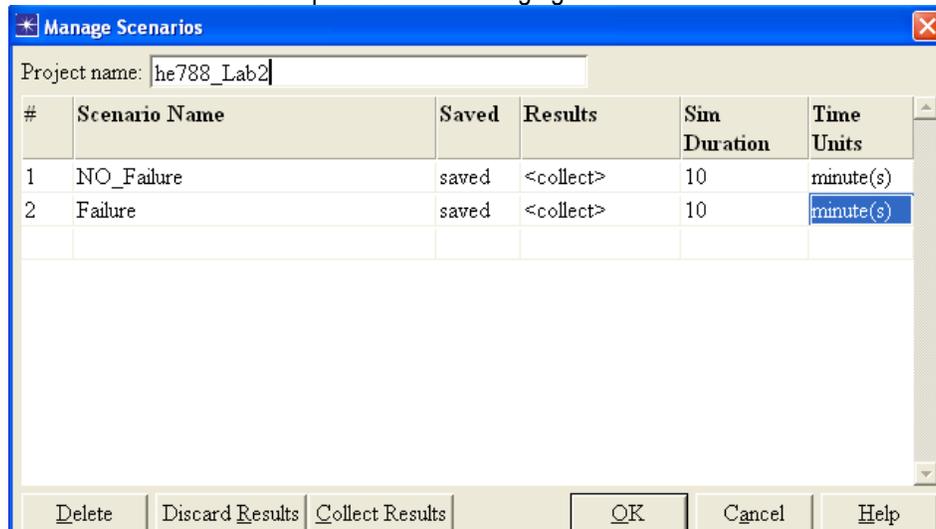


Figure 6

3. Click **Ok** to run the two simulations.
4. After the two simulation runs complete, one for each scenario, click **Close** ⇒ Save your project.

## View the Results

*Compare the Number of Updates:*

1. Select **Compare Results** from the **Results** menu.
2. Change the drop-down menu in the right-lower part of the *Compare Results* dialog box to **Stacked Statistics** as shown.
3. Select the **Total Number of Updates** statistics for **Router1** and click **Show**.
4. You should get two graphs, one for each scenario. Right-click on each and select **Draw Style** ⇒ **Bar**.

*Obtain the IP Addresses:*

Before checking the contents of the routing tables, we need to determine the IP address information for all interfaces in the current network. Recall that these IP addresses are



assigned automatically during simulation, and we set the global attribute IP Interface Addressing Mode to export this information to a file.

1. From the **File** menu choose **Model Files** ⇒ **Refresh Model Directories**. This causes Opnet IT Guru to search the model directories and update the list of files.
2. From the **File** menu choose **Open** ⇒ from the drop-down menu choose **Generic Data File** ⇒ select the <your student number> **EE2480\_Lab2-NO\_Failure-ip\_addresses** file (the other file created from the Failure scenario should contain the same information ⇒ click **OK**).
3. The **gdf** file should show the IP addresses assigned to the interface of **Router1** in our network. The Subnet Mask associated with every interface indicates that the address of the subnetwork to which the interface is connected.
4. Draw the topology of the network and write down the IP addresses associated with Router1 as well as addresses assigned to each subnetwork.

Compare the Routing Tables Content:

1. To check the content of the routing tables in **Router1** for both scenarios:
  - a. Go to **Results** menu ⇒ **Open Simulation Log** ⇒ Expand the hierarchy on the left as shown below ⇒ click on the field **COMMON ROUTE TABLE**.
2. Carry out the previous step for both scenarios.

**Lab Report:** In your report present all obtained results and give detailed explanation.

## Laboratory 3

### Network Design

The objective of this lab is to demonstrate the basics of designing a network, taking into consideration the users, services, and locations of the hosts.

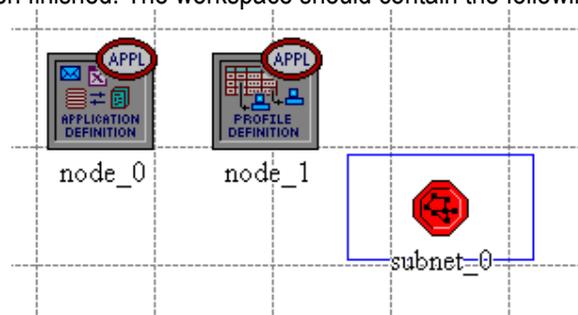
#### Create a New Project

1. Start OPNET IT Guru Academic Edition ⇒ Choose New from the File menu.
2. Select Project and click OK ⇒ Name the project <your student number>\_NetDesign and the scenario SimpleNetwork ⇒ click Ok.
3. In the Startup Wizard: Initial Topology dialog box, make sure that Create Empty Scenario is selected ⇒ click Next ⇒ choose Miles from the Size drop-down menu and assign 1 for both X Span and Y Span ⇒ click Next twice ⇒ click OK

#### Create and configure the Network

Initialize the Network:

1. The Object Palette dialog box should be now on the top of your project space. If it is not there open it by clicking . Make sure that the internet\_toolbox is selected from the pull down menu on the object palette.
2. Add to the project workspace the following objects from the palette: Application Config, Profile Config, and a subnet. Application Config is used to specify applications that will be used to configure users profiles. Profile Config describes the activity patterns of a user or group in terms of the applications used over a period of time. You must define the applications using the Application Config before using this object.
  - a. To add an object from the palette, click on its icon in the object palette ⇒ move your mouse to the workspace ⇒ left-click to place the object. Right-click when finished. The workspace should contain the following three objects:



Configure the services:



1. Right-click on Application Config node ⇒ Edit Attributes ⇒ Change the name attribute to Applications ⇒ Change the Application Definitions attribute to Default ⇒ Click OK.
2. Right-click on the Profile Config node ⇒ Edit Attributes ⇒ Change the name attribute to Profiles ⇒ Change the Profile Configuration attribute to Sample Profiles ⇒ Click OK.

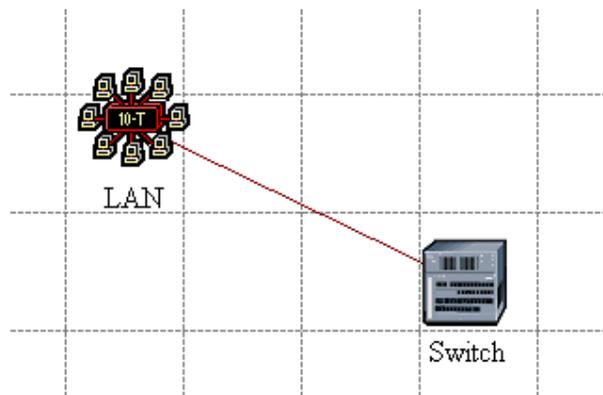
Sample Profiles provides patterns of applications employed by users such as engineers, researchers, salespeople, and multimedia users.

### Configure a subnet:

1. Right-click on the subnet node ⇒ Edit Attributes ⇒ Change the name attribute to Engineering and click OK.
2. Double-click on the Engineering node. You get an empty workspace, indicating that the subnet contains no objects.
3. Open the Object Palette and make sure it is still set to internet\_toolbox.
4. Add the following items to the subnet workspace: 10BaseT LAN, ethernet16Switch, and a 10BaseT link to connect the LAN with the Switch ⇒ Close the palette.
5. Right-click on the 10BaseT LAN node ⇒ Edit attributes ⇒ Change the name attribute to LAN ⇒ observe that the Number of Workstations attribute has a value of 10. Click in the Value column for the Application: Supported Profiles attribute, and select Edit. You should get a table in which you should do the following:
  - a. Set the number of rows to 1
  - b. Set the Profile Name to Engineer. Note: Engineer is one of the “sample” profiles provided within the Profile Config object.
  - c. Click OK twice.

The object we just created is equivalent to a 10-workstation star topology LAN. The traffic generated from the users of this LAN resembles that generated by “engineers”.

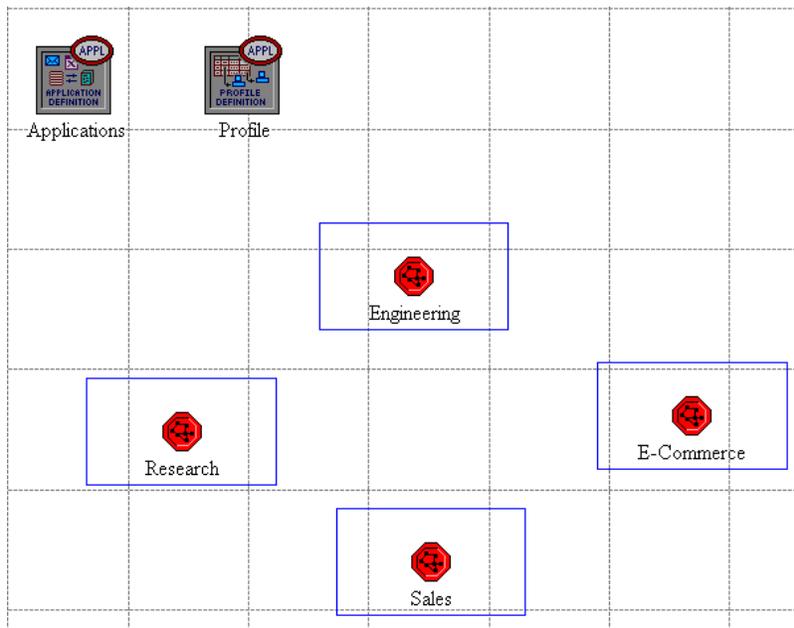
6. Rename the ethernet16Switch to Switch
7. The subnet should look like the one in figure below.



8. Save your project

### Configure All Departments:

1. Now you have completed the configuration of the Engineering Department subnet. To go back to the main project space, click the Go to the higher level button .
2. Make three copies of the Engineering subnet we just created. Click on the Engineering node ⇒ From the Edit menu, select Copy ⇒ from the Edit menu select Paste three times, placing the subnet in the workspace after each, to create the new subnets.
3. Rename (right-click on the subnet and select Set Name) and arrange the subnets as shown below:

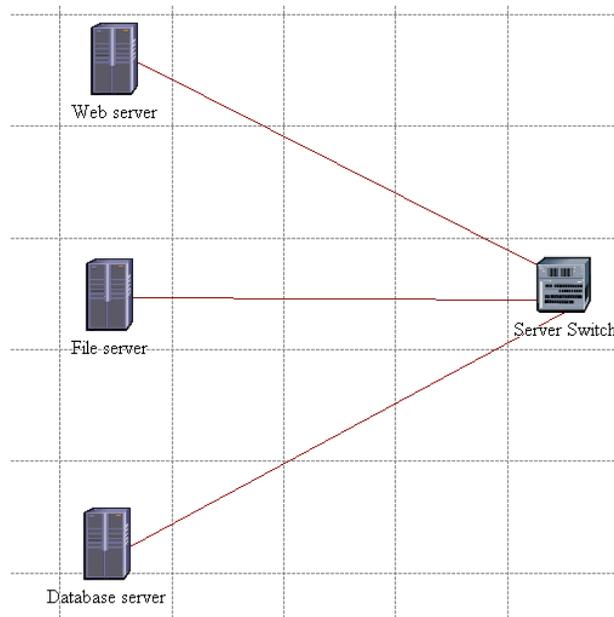


4. Double-click the Research node ⇒ Edit the attributes of its LAN ⇒ Edit the value of the Application: Supported Profile attribute ⇒ Change the value of the Profile Name from Engineer to Researcher ⇒ Click OK twice ⇒ go to the higher level by clicking the  button.
5. Repeat step 4 with the Sales node and assign to its Profile Name the profile Salesperson.
6. Repeat step 4 with the E-Commerce node and assign to its Profile Name the profile E-Commerce Customer.
7. Save the project .

### Configure the Servers:

Now we need to implement a subnet that contains the servers. The servers have to support the applications defined in the profiles we deployed. You can double-check these applications by editing the attributes of our Profile node. Inspect each row under the Applications hierarchy, which in turn, is under the Profile Configuration hierarchy. You will see that we need servers that support the following applications: Web browsing, Email, Telnet, File Transfer, Database, and File Print.

1. Open the Object Palette and add a new subnet ⇒ rename the new subnet to Servers  
⇒ double-click the Servers node to enter its workspace.
2. From the Object Palette, add three ethernet\_servers, one ethernet16\_switch, and three 10BaseT links to connect the servers with the switch.
3. Close the Object Palette
4. Rename the servers and the switch as follows:



5. Right-click on each one of the above servers and Edit the value of the Application: Supported Services attribute.
  - a. For the Web Server add four rows to support the following services: Web Browsing (Light HTTP1.1), Web Browsing (Heavy HTTP1.1), Email (Light) and Telnet Session (Light)
  - b. For the File Server add two rows to support the following services: File Transfer (Light) and File Print (Light).
  - c. For the Database Server add one row to support the following service: Database Access (Light).
6. Go back to the project space by clicking the Go to the higher level button.
7. Save the project

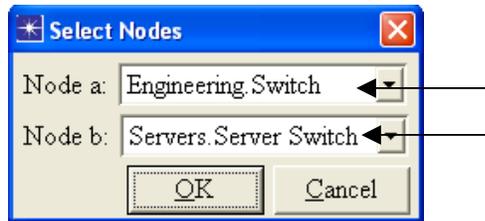
### Connect the Subnets:

Now all subnets are ready to be connected together.

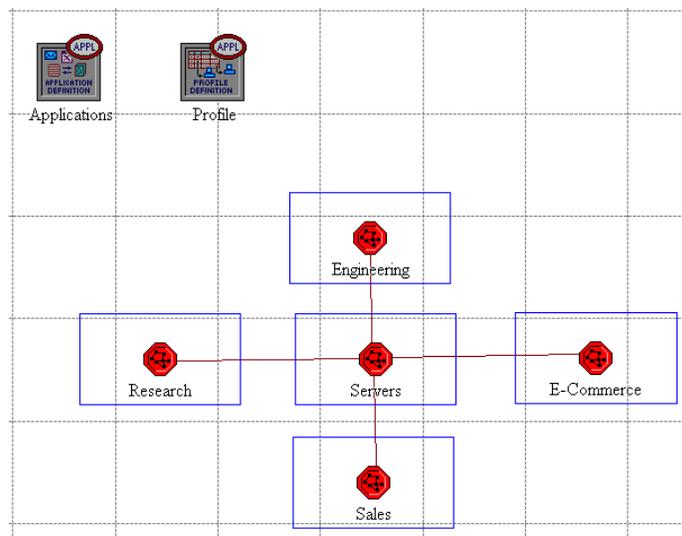
1. Open the Object Palette and add four 100BaseT links to connect the subnets of the departments to the Servers subnet.



As you create each link, make sure that it is configured to connect the “switches” in both subnets to each other. Do this by choosing them from the drop-down menu as follows:



2. Close the Object Palette.
3. Now your network should resemble the following one:



4. Save the project.

### Choose the Statistics

To test the performance of our network we will collect one of the many available statistics as follows:

1. Right-click anywhere in the project workspace and select Choose Individual Statistics from the pop-up menu.
2. In the Choose Results dialog box, choose Global statistics => HTTP => Page Response Time (seconds). Page response time is the required time to retrieve the entire page.
3. Click OK.

### Configure the Simulation

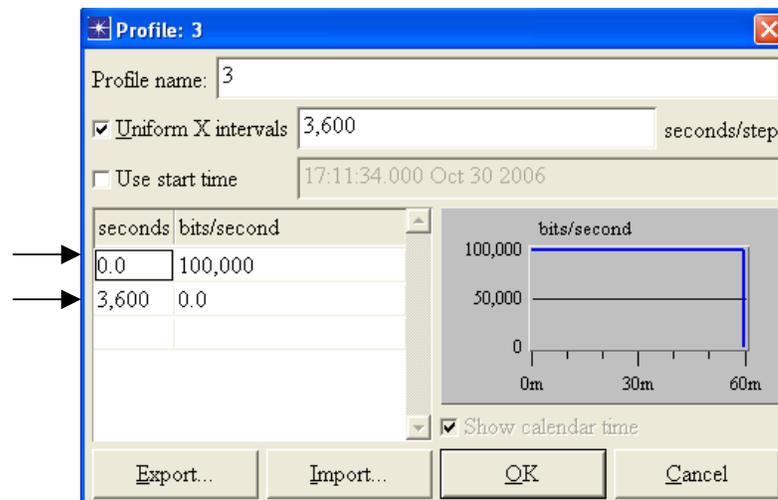
Here we need to configure the duration of the simulation

1. Click on the Configure/Run Simulation button .
2. Set the duration to be 30.0 minutes
3. Press OK

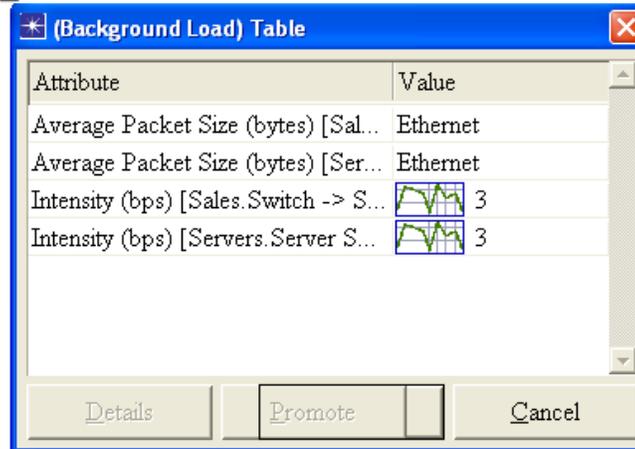
### Duplicate the Scenario

In the network we just created we assumed that there is no background traffic already in the links. In real networks, the links usually have some existing background traffic. We will create a duplicate of the SimpleNetwork scenario but with background utilisation in the 100BaseT links. Link utilisation is the percentage of the used link bandwidth.

1. Select Duplicate Scenario from the Scenarios menu and give it the name BusyNetwork ⇒ click OK.
2. Select all the 100BaseT links simultaneously (click on all of them while holding the Shift key) ⇒ Right-click on anyone of them ⇒ Edit Attributes ⇒ Check the Apply Changes to Selected Objects check box.
3. Click on the value of Background Load ⇒ Edit ⇒ Average Packet Size (bytes) ⇒ choose Ethernet for **BOTH** directions.
4. For the Intensity (bps), choose Edit from the pop-up menu and enter the following variables



5. Click OK
6. Repeat step 4 and 5 for defining the background load in the opposite direction
7. your window of background load table should look like below.

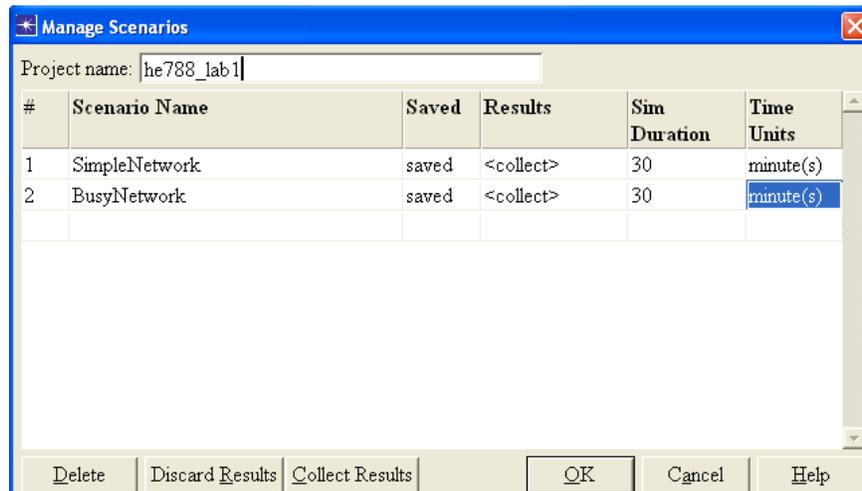


8. Save your project

### Run the Simulation

To run the simulation for both scenarios simultaneously:

1. Go to the Scenarios menu ⇒ Select Manage Scenarios.
2. Change the values under the Results column to <collect> for both scenarios. Compare to the following figure.
- 3.



4. Click OK to run the two simulations.
5. After the two simulation runs complete (one for each scenario), click Close.
6. Save the project



### **View the Results**

To view and analyse the results:

1. Select Compare Results from the Results menu
2. Change the drop-down menu in the lower-right part of the Compare Results dialog box from As Is to time\_average.
3. Select the Page Response Time (seconds) statistics and click Show.

## Laboratory 4

### Queuing Disciplines: Order of packet Transmission and Dropping

The objective of this lab is to examine the effect of different queuing disciplines on packet delivery and delay for different services.

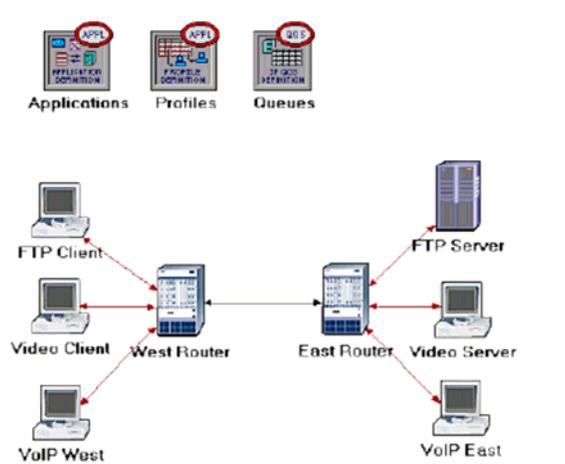
#### Create a New Project

1. Start **OPNET IT Guru Academic Edition**  Choose **New** from the **File** menu.
2. Select **Project** and click **OK**  Name the project **<your initials>\_Queues**, and the scenario **FIFO**  Click **OK**.
3. In the *Startup Wizard: Initial Topology* dialog box, make sure that **Create Empty Scenario** is selected  Click **Next**  Select **Campus** from the *Network Scale* list  Click **Next** three times  Click **OK**.

#### Create and Configure the Network

##### Initialize the Network:

1. Open the *Object Palette* dialog box. Make sure that the **internet\_toolbox** item is selected from the pull-down menu on the object palette.
2. Add to the project workspace the following objects from the palette: **Application Config**, **Profile Config**, **QoS Attribute Config**, five **ethernet\_wkstn**, one **ethernet\_server**, and two **ethernet4\_slip8\_gtwy** routers.  
Note that The **QoS Attribute Config** node defines attribute configuration details for protocols supported at the IP layer. These specifications can be referenced by the individual nodes using symbolic names. It defines different queuing profiles such as FIFO, WFQ, priority queuing, and custom queuing.
3. Connect both routers together with a bidirectional **PPP\_DS1** link.
4. Connect the workstations and the server to the routers using bidirectional **10Base\_T** links as shown.



5. Rename the objects you added as shown and then save your project.

**Application Config** is used to specify applications that will be used to configure users profiles.

1. Right-click on the **Applications** node  **Edit Attributes**  Expand the **Application Definitions** hierarchy  Set **rows** to 3  Name the rows: **FTP Application**, **Video Application**, and **VoIP Application**.

i) Go to the **FTP Application** row  Expand the **Description** hierarchy  Assign **High Load** to **Ftp**  Click on the **High Load** value and choose **Edit** from the drop-down menu  Assign **Constant(10)** to **Inter-Request Time**  Assign **Constant(1,000,000)** to **File Size**. Keep the **Type of Service (ToS)** as **Best Effort (0)**. Press **Enter** twice. Note that **Type of Service (ToS)** is assigned to the IP packets and It represents a session attribute that allows packets to be provided the appropriate service in the IP queues.

ii) Go to the **Video Application** row  Expand the **Description** hierarchy  Assign **Low Resolution Video** to **Video Conferencing**  Click on the **Low Resolution Video** value and choose **Edit**  Edit the value of the **Type of Service** field (the **Configure TOS/DSCP** window appears)  From the dropdown menu, assign **Streaming Multimedia (4)** to **ToS**  Press **Enter** twice.

iii) Go to the **VoIP Application** row  Expand the **Description** hierarchy  Assign **PCM Quality Speech** to **Voice**. Click on **PCM Quality Speech** and make sure that the ToS assigned to it is **Interactive Voice (6)**.

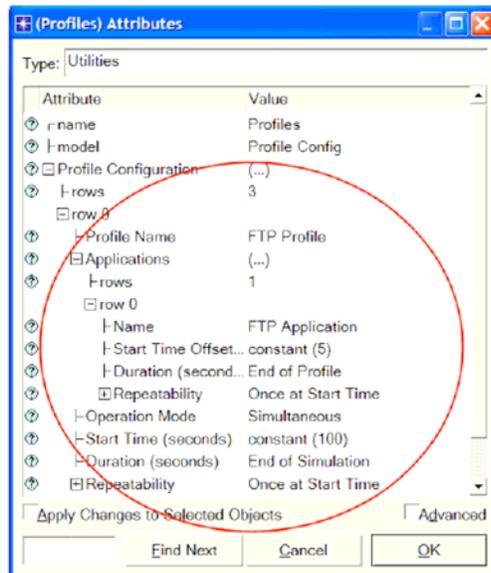
2. Click **OK** and then save your project.

**Configure the Profiles:**

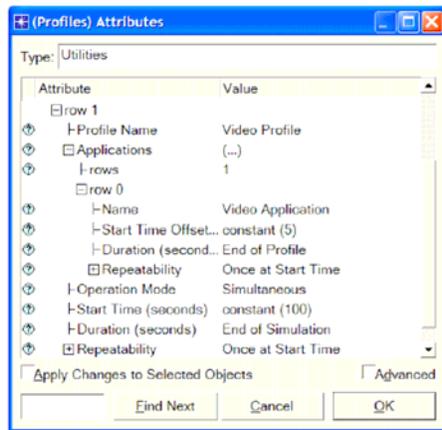
**Profile Config** describes the activity patterns of a user or group of users in terms of the applications used over a period of time.

1. Right-click on the **Profiles** node  **Edit Attributes**  Expand the **Profile Configuration** hierarchy  Set **rows** to 3.

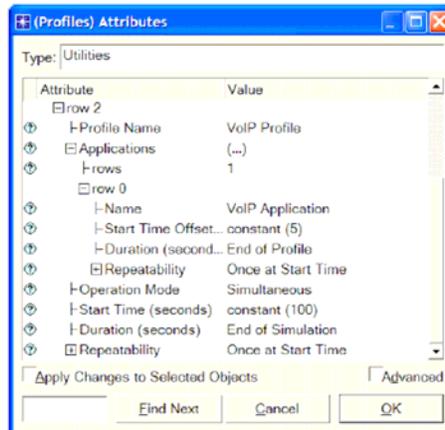
i. Name and set the attributes of row 0 as shown:



ii. Name and set the attributes of row 1 as shown in next page:



iii. Name and set the attributes of row 2 as shown below:



2. Click **OK** and then save your project.

#### Configure the Queues:

We will keep the default queuing profiles that are defined in our **Queues** object. It is recommended that you check out the configuration of the FIFO, PQ, and WFQ profiles.

#### Configure the Workstations and Servers:

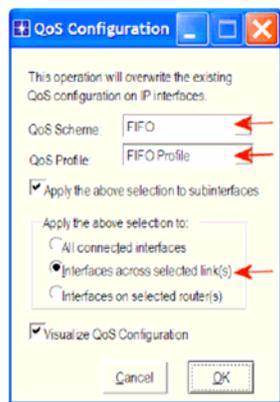
1. Right-click on the **FTP Client**  **Edit Attributes**  Expand the **Application: Supported Profiles** hierarchy  Set **rows** to 1  Set **Profile Name** to **FTP Profile**  Click **OK**.
2. Right-click on the **Video Client**  **Edit Attributes**  Expand the **Application: Supported Profiles** hierarchy  Set **rows** to 1  Set **Profile Name** to **Video Profile**  Click **OK**.
3. Right-click on the **VoIP West**  **Edit Attributes**.
  - i) Expand the **Application: Supported Profiles** hierarchy  Set **rows** to 1  Set **Profile Name** to **VoIP Profile**.
  - ii) Edit the **Application: Supported Services** value  Set **rows** to 1  Set **Service Name** to **VoIP Application**  Click **OK** twice.
4. Right-click on the **VoIP East**  **Edit Attributes**.



- i) Expand the **Application: Supported Profiles** hierarchy  Set **rows** to 1  Set **Profile Name** to **VoIP Profile**.
  - ii) Edit the **Application: Supported Services** value  Set **rows** to 1  Set **Service Name** to **VoIP Application**  Click **OK** twice.
5. Right-click on the **FTP Server**  **Edit Attributes**  Edit the **Application: Supported Services** value  Set **rows** to 1  Set **Service Name** to **FTP Application**  Click **OK** twice.
  6. Right-click on the **Video Server**  **Edit Attributes**  Edit the **Application: Supported Services** value  Set **rows** to 1  Set **Service Name** to **Video Application**  Click **OK** twice.
  7. Save your project.

### Configure the Routers:

1. Click on the link connecting the **East** and **West** routers to select it  From the **Protocols**, menu choose **IP** → **QoS** → **Configure QoS**.
2. Make sure the selected items are as shown in the following *QoS Configuration* dialog box  Click **OK**.



- Note:* Since the **Visualize QoS Configuration** radio button is checked, the link is colored based on the QoS scheme used.
3. Save your project.

### Choose the Statistics

To test the performance of the applications defined in the network, we will collect one of the many available statistics as follows:

1. Right-click anywhere in the project workspace and select **Choose Individual Statistics** from the pop-up menu.
2. In the *Choose Results* dialog box, select the following **global** statistic:
  - i) IP=>Traffic Dropped (packets/sec)
  - ii) FTP=> Traffic received (packets/sec)
  - iii) Video Conferencing => Traffic received (Bytes/sec)
  - iv) Voice=> Packet Delay variation, Packet End-to-End delay, Traffic received (Bytes/sec)
3. Click on the link that connects east Router to West Router. Right click and choose Individual DES statistics. Under the point-to-point hierarchy, choose (queuing delay ←)
4. Click **OK** and then save your project.

### Configure the Simulation



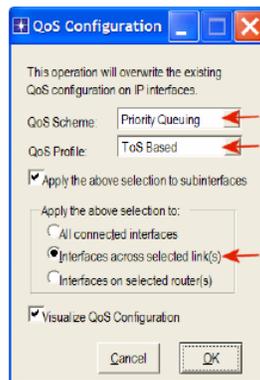
Here we need to configure the duration of the simulation:

1. Click on  and the *Configure Simulation* window should appear.
2. Set the duration to be **200 seconds**.
3. Click **Apply** and then save your project.

### Duplicate the Scenario

In the network we just created, we used the FIFO queuing discipline in the routers. To analyze the effect of different queuing disciplines, we will create two more scenarios to test the Priority Queuing (PQ) and Weighted Fair Queuing (WFQ) disciplines.

- A. Select **Duplicate Scenario** from the **Scenarios** menu and give it the name **PQ**  Click **OK**.
1. Click on the link connecting the **East** and **West** routers to select it  From the **Protocols** menu choose **IP** → **QoS** → **Configure QoS**.
  2. Make sure the selected items are as shown in the following *QoS Configuration* dialog box  Click **OK**.



3. Save your project.

- B. Select **Duplicate Scenario** from the **Scenarios** menu and give it the name **WFQ**  Click **OK**.

1. Click on the link connecting the **East** and **West** routers to select it  From the **Protocols** menu choose **IP** → **QoS** → **Configure QoS**.
2. Make sure the QoS Scheme is set Weighted Fair Queuing and QoS profile is ToS Based  Click **OK**.
3. Save your project.

### Run the Simulation

To run the simulation for the three scenarios simultaneously:

1. Go to the **Scenarios** menu  Select **Manage Scenarios**.
2. Change the values under the **Results** column to <collect> (or <recollect>) for the three scenarios. Put the simulation period to 200 seconds for all scenarios
3. Click **OK** to run the three simulations.
4. After the simulation completes the three runs, one for each scenario, click **Close**.
5. Save your project.

### View the Results

To view and analyze the results:



1. Select **Compare Results** from the **Results** menu.
2. Select the IP **Traffic Dropped** statistic and click **Show**. The resulting graph should resemble the one below. *Note:* The shown graph is the result of zooming into the region of interest on the original graph.
3. Create the graph for **Video Conferencing Traffic Received**:
4. Create the graph for **Voice Traffic Received**:
5. Create graphs for **Voice Packet End-to-End Delay** and **Voice Packet Delay Variation**.
6. Create graphs for Queuing Delay for West Router←→East Router link

**Note1:** if the graph is not shown for one of the scenarios, there might be an overlap of the presented results)

**Note2:** Zoom the graphs into the region of interests to get the best visualization

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**Question 1: Explain and compare the three queuing disciplines**

**Question 2: Analyze the graphs we obtained and explain the effect of queuing discipline on the performance of the three applications.**

**Question 3: Name three reasons for dropping an IP packet by a router. Which queuing discipline has higher queuing delay in the simulation. Explain why?**

## LABORATORY 5

### IP ADDRESSING AND SUBNETTING

**Assessment:** You need to produce a HANDWRITTEN report. The Report should be submitted with an appropriate cover page containing your name and the module name. The report should consist of answers to questions Q1 to Q4.

1. Run Advanced Subnet Calculator from your Desktop. This simple software can calculate the number of subnets that can be built using specified addresses and specified subnet masks.
2. In the Advanced Subnet Calculator window, press the *Classfull Subnet Calculator* tab. Type in a class C IP address (e.g. 192.168.123.144), and use the following subnet masks 255.255.255.0; 255.255.255.128; 255.255.255.192. In all cases, press *Generate Subnets* button. Note the host range and the subnet size of all subnets. Note the number of mask bits, number of subnets and number of host bits.
3. Now in the same window use a class B IP address, e.g. 132.168.123.144 and repeat the process with subnet masks 255.255.0.0; 255.255.128.0; 255.255.255.0

**Q1) Explain the concept of subnetting and the concept of subnet masks. Why do we use subnetting? How do we know which bits are used to identify the network?**

**Q2) Present and discuss the results in Lab report. Why is it possible to make two subnets when a class C address and subnet mask of 255.255.255.128 was used? What happens when 255.255.255.255 is used as a subnet mask? What is the difference in the results when class B address is used?**

4. Press the CIDR Calculator tab. Enter address 132.168.123.144. Choose CIDR subnet mask to be 15 bits long. Generate 4, 32, 128 and 2048 subnets. Note the number of subnet bits needed for each case. Note the Host range and the Subnet Size for each case.

**Q3) Explain the obtained results.**

**Q4) Consider a router that interconnects three subnets: subnet 1, subnet 2, and subnet 3. Suppose all of the interfaces in each of these three subnets are required to have a prefix 223.1.17/24. Also suppose that subnet 1 is required to support up to 125 interfaces, and subnets 2 and 3 are each required to support up to 60 interfaces. Provide three network addresses (of the form a.b.c.d/x) that satisfy these constraints. You can use Advanced Subnet Calculator to solve this problem.**